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Exercise therapy for the management of femoroacetabular impingement syndrome: preliminary results of clinical responsiveness

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Abstract: OBJECTIVE To investigate the responsiveness to exercise therapy of patients with femoroacetabular impingement syndrome (FAIS), and differences in hip function, strength and morphology between responders vs. non-responders. METHODS Patients with FAIS underwent 12 weeks of semi-standardized and progressive exercise therapy. Good therapy outcome (responders) vs. poor therapy outcome (non-responders) was determined at week 18 with the Global Treatment Outcome for hip pain. Hip function was evaluated using the Hip Outcome Score (HOS) activities of daily living (ADL) and Sport at baseline, week 6, 12 and 18. Hip muscle strength and dynamic pelvic control were evaluated using dynamometry and video analysis, respectively, at baseline, week 12 and 18. Hip morphology was evaluated with imaging at baseline. RESULTS Thirty-one patients (mean age: 24 years) were included. Sixteen (52%) patients were responsive and 15 (48%) were not responsive to exercise therapy. Only responders improved HOS ADL and HOS Sport by 10 (95% CI: 7 to 14, P<0.001) and 20 points (95%CI: 15 to 25, P<0.001), respectively, and hip abductor strength by 0.27 Nm/kg (95%CI: 0.18 to 0.36, P<0.001). The prevalence of patients showing good dynamic pelvic control only increased in responders (44%, P=0.029). The prevalence of severe cam morphology was higher in non-responders than responders (40% vs. 6%, P=0.037). CONCLUSION Half of patients with FAIS benefits from exercise therapy at short term. Responsiveness to hip abductor strength and dynamic pelvic control improvements is associated with good therapy outcome, whereas presence of severe cam morphology is associated with poor therapy outcome. This article is protected by copyright. All rights reserved.

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Exercise therapy for the management of femoroacetabular impingement syndrome: preliminary results of clinical responsiveness

Nicola C Casartelli, PhD[1,2], Mario Bizzini, PT PhD[1], Nicola A Maffiuletti, PhD[1], Reto Sutter, MD[3,4], Christian W Pfirrmann, MD MBA[3,4], Michael Leunig, MD[5], Florian D Naal, MD[5]

[1]*Human Performance Lab, Schulthess Clinic, Zurich, Switzerland*

[2]*Laboratory of Exercise and Health, ETH Zurich, Zurich, Switzerland*

[3]*Department of Radiology, Orthopaedic University Hospital Balgrist, Zurich, Switzerland*

[4]*Faculty of Medicine, University of Zurich, Zurich, Switzerland*

[5]*Department of Orthopaedic Surgery, Schulthess Clinic, Zurich, Switzerland*

Corresponding author:

Nicola C Casartelli, PhD

Human Performance Lab, Schulthess Clinic

Lengghalde 2, 8008 Zurich, Switzerland

Phone: +41 (0)44 385 79 71, Fax: +41 (0)44 385 75 90

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Email: nicola.casartelli@kws.ch

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ABSTRACT

Objective: To investigate the responsiveness to exercise therapy of patients with femoroacetabular impingement syndrome (FAIS), and differences in hip function, strength and morphology between responders vs. non-responders.

Methods: Patients with FAIS underwent 12 weeks of semi-standardized and progressive exercise therapy. Good therapy outcome (responders) vs. poor therapy outcome (non-responders) was determined at week 18 with the Global Treatment Outcome for hip pain. Hip function was evaluated using the Hip Outcome Score (HOS) activities of daily living (ADL) and Sport at baseline, week 6, 12 and 18. Hip muscle strength and dynamic pelvic control were evaluated using dynamometry and video analysis, respectively, at baseline, week 12 and 18. Hip morphology was evaluated with imaging at baseline.

Results: Thirty-one patients (mean age: 24 years) were included. Sixteen (52%) patients were responsive and 15 (48%) were not responsive to exercise therapy. Only responders improved HOS ADL and HOS Sport by 10 (95% CI: 7 to 14, P<0.001) and 20 points (95%CI: 15 to 25, P<0.001), respectively, and hip abductor strength by 0.27 Nm/kg (95%CI: 0.18 to 0.36, P<0.001). The prevalence of patients showing good dynamic pelvic control only increased in responders (44%, *P*=0.029). The prevalence of severe cam morphology was higher in non-responders than responders (40% vs. 6%, *P*=0.037).

Conclusion: Half of patients with FAIS benefits from exercise therapy at short term. Responsiveness to hip abductor strength and dynamic pelvic control improvements is associated with good therapy outcome, whereas presence of severe cam morphology is associated with poor therapy outcome.

Keywords: Femoroacetabular impingement syndrome; Exercise therapy; Pain; Muscle strength; Morphology

SIGNIFICANCE AND INNOVATIONS

- Some but not all patients with FAIS benefit at short term from exercise therapy;
- The responsiveness to hip abductor strength and dynamic pelvis control improvements following therapy is associated with good exercise therapy outcome in patients with FAIS;
- The presence of severe cam morphology is associated with poor exercise therapy outcome in patients with FAIS.

Femoroacetabular impingement syndrome (FAIS) is a pathomechanism of the hip joint, which may cause debilitating hip pain in young adults and result in the development of hip osteoarthritis (OA) (1,2). FAIS is caused by abnormal morphology of the proximal femur and/or acetabulum, in conjunction with repetitive, rigorous and supraphysiological hip motion (1,3). Hip surgery has long been considered the main treatment option for FAIS, since the underlying pathomechanism is thought to be primarily caused by abnormal hip morphology (1). High-level evidence demonstrating the actual effectiveness of hip surgery for the management of FAIS is growing (4,5), but the best surgical indications are still subject of discussion (6). In contrast, non-surgical treatment options for FAIS have been largely overlooked (7), even if their failure should be the most important indication for surgery (7,8). In addition, valid non-surgical treatment options are required for those patients, who are not candidates for hip surgery (7,9).

Recently, a rationale has been proposed that explains how exercise therapy aimed at improving the neuromuscular function of the hip, trunk and lower limbs might be effective for the non-surgical management of FAIS (10). Dynamic hip instability due to hip muscle weakness (11,12) and impaired pelvic control (13-15) may lead to exaggerated mechanical loading of the acetabular labrum (16), and upregulation of its nociceptive receptors (17). Therefore, it was suggested that improving the dynamic stability of the femoroacetabular joint through exercise therapy aimed at improving hip muscle strength and pelvis control during functional tasks (14), may reduce the mechanical loading and contact stress on the joint structures, and in turn downregulate nociceptor activity (10).

As the need to elucidate the effectiveness of non-surgical treatment protocols for FAIS, and to identify the characteristics of patients who can benefit from them (7) is of primary clinical relevance, the aims of this preliminary study were (i) to investigate the responsiveness of patients with FAIS to exercise therapy, and (ii) to evaluate the differences in hip function, hip muscle strength, dynamic pelvic control, as well as hip morphology and intra-articular damage patterns between patients responsive vs. non-responsive to exercise therapy.

PATIENTS AND METHODS

Study design

Patients with FAIS underwent a 12-week semi-standardized and progressive exercise therapy program. Hip morphology and intra-articular damage were assessed with imaging at baseline. Hip pain, function and quality of life were evaluated with patient-reported questionnaires at baseline, week 6, 12 and 18. Hip muscle strength and dynamic pelvic control were respectively assessed with dynamometry and video analysis at baseline, week 12 and 18. The study was conducted according to the Declaration of Helsinki. The protocol was approved by the Ethics Committee of the Canton of Zurich, Switzerland and registered in ClinicalTrials.gov (trial registration number: NCT02368483).

Participants

Patients were recruited by two expert hip surgeons (NAF, ML) from the Department of Orthopaedic Surgery, Schulthess Clinic, Zurich, Switzerland. The inclusion criteria were: diagnosis of FAIS based on symptoms, clinical examination and imaging findings (4), age between 18 and 35 years, no previous standardized non-surgical treatment, and no urgent indication for hip surgery based on surgeons' opinion, such as early chondral degeneration in combination with severe cam morphology. Exclusion criteria were: previous hip surgery, surgery on the lower extremities in the last 6 months, hip dysplasia (lateral centre edge angle <20°) (18), hip osteoarthritis (Tönnis grade >1) (18), initiation of opioid analgesia or corticosteroid hip injections in the last 3 months, BMI >35 kg/m^2 and cardiopulmonary diseases. All patients signed an informed consent before participating in the study.

Intervention

All patients received education from the respective hip surgeons, including advices on activity and lifestyle modifications (4). If needed, the use of oral analgesia including non-steroidal anti-inflammatory drugs was permitted. The exercise therapy lasted 12 weeks and consisted of 4 sessions/week (total of 48 sessions). Two face-to-face sessions/week were conducted at the Schulthess Clinic, Zurich, Switzerland under the supervision of a therapist (24 supervised sessions), and 2 sessions/week were conducted at home (24 home-based sessions). The semi-standardized protocol was aimed at improving dynamic hip joint stability with bilateral hip-specific and functional lower limb strengthening, core stability and postural balance exercises (10). The protocol consisted of 3 phases (Phase I to III) with progressively increasing neuromuscular loading (Supplementary Table S1). Therapists were provided with a booklet including a list of exercises that could be used within each training phase and exercise type. Therapists had the freedom to design each session by choosing from among the exercises within each training phase and exercise type, based on the needs and capacities of patients. Supervised sessions lasted 45 to 60 min and included a warm up, 4 hip-specific strengthening exercises, 2 functional lower limb strengthening exercises (except in Phase I), 2 core stability exercises, and 2 postural balance exercises. Home-based sessions lasted about 15 min and included a warm up, 1 hip abductor or extensor strengthening exercise, 1 functional lower limb strengthening exercise (except in Phase I), and 1 core stability exercise. Feedbacks for correct task execution and pelvic control were provided to patients after the performance of all exercises. The training volume for each exercise type was as follows: 1 series of 20 s for stretching exercises; 3 series of 10-15 repetitions for isoinertial exercises; 3 series of 10-40 s for isometric exercises; 3 series of 30-60 s for postural balance exercises. Adherence to the intervention was controlled by asking therapists and patients to complete a protocol sheet after each supervised and home-based session, respectively.

Assessments

Therapy feasibility

Patient eligibility and enrolment, therapy adherence (≥80% therapy session attendance), patients lost to follow-up, hip surgery rate until 1-year follow-up, and adverse event occurrence were reported.

Therapy responsiveness

Exercise therapy responsiveness was evaluated using the Global Treatment Outcome (GTO) for hip pain (19). The GTO is a single-item patient-reported questionnaire asking about changes in hip pain with respect to baseline. The five response options are: much better, better, somewhat better, unchanged, worse. Good outcome was achieved if patients reported hip pain to be much better or better, while poor outcome if hip pain was somewhat better, unchanged or worse at week 6, 12 and 18 compared with baseline (20). The GTO at week 18 was used to categorize patients as responders (good therapy outcome) and non-responders (poor therapy outcome). Scales like the GTO are very frequently used in clinical research with musculoskeletal patients to assess the significance of change following an intervention from the individual patient perspective (21). The GTO has been specifically used in patients with FAIS to evaluated changes following hip surgery (19,20), demonstrating good construct validity (20).

Hip pain, function and quality of life

Hip pain and function was evaluated using the Hip Outcome Score (HOS) (22). Two independent scores were obtained: one for activities of daily living (HOS ADL: 19 items, 17 scored) and one for sport activities (HOS Sport: 9 items, 9 scored). Health-related quality of life was evaluated using the Euro Quality of Life - Visual Analogue Scale (EQ-VAS) (23). The scores range from 0 to 100, where 100 indicates the best possible score.

Hip muscle strength

Maximal voluntary isometric strength of the involved hip was evaluated with stabilized dynamometry (Nicholas Manual Muscle Tester, Lafayette Inc., Lafayette, IN, USA) for hip abductors, adductors, internal and external rotators, and with isokinetic dynamometry (Biodex System 4, Biodex Medical Systems, Shirley, New York, USA) for hip flexors and extensors. Test positions have been previously described elsewhere (11). For each muscle group, patients first completed 2 submaximal familiarization trials followed by 3-4 maximal trials. The rest interval between trials was 60 s. For each muscle group, the highest torque normalized to body mass was retained.

Dynamic pelvic control

Dynamic pelvic control was evaluated with a visual rating scale during the execution of 2 challenging functional tasks: single-limb squat and hop lunge on the involved side (15,24). Standardized instructions for correct task execution were provided to the patients (15). Patients first completed 1-2 familiarization trials followed by 4 recorded trials. Functional tasks were recorded using a video camera (Logitech HD Pro Webcam C920, Logitech, Lausanne, Switzerland), which was positioned frontal to the patient during the first 2 recorded trials and lateral to the patient during the second 2 recorded trials (15). A highly-experienced physical therapist (MB) retrospectively analysed the videos and evaluated dynamic pelvic control using a segmental rating scale (15,24). The therapist evaluated if the pelvis dropped on the contralateral side in the frontal plane or rotated medially in the transversal plane maintaining the vertical body axis (pelvis 1), and if the pelvis moved away from the vertical body axis in the frontal plane (pelvis 2). For both pelvis 1 and 2, dynamic control was scored as 1 (good pelvis control) or 0 (poor pelvis control). Average rating scores were retained. Acceptable intra-rater agreement was observed for pelvic control rating as scored by a highly-experienced physical therapist, with mean agreement coefficients ranging between 0.74 to 0.67 for single-limb squat, and 0.83 and 0.78 for single-limb hop lunge (15).

Hip imaging

The presence of cam morphology, acetabular labrum alterations and chondral damage in the involved hip were evaluated by two experienced radiologists (RS, CWP) with magnetic resonance imaging (MRI) arthrography (1.5 Tesla high-field system, Magnetom Avanto, Siemens Medical Solutions, Erlangen, Germany). Cam morphology was determined using the cam severity grading system and alpha angle. The cam severity grading is a semiquantitative scoring system that assesses the maximal offset at the head-neck junction on radial sequences (25). This grading system ranges from 0 to 3, where 0=normal, 1=possible deformity, 2=definite deformity, and 3=severe deformity. The alpha angle was measured on radial oblique MRI at the anterior, anterosuperior and superior segments (26).

The maximal alpha angle was retained. Acetabular labral alterations were evaluated on radial MRI as a linear band of high-signal intensity detected in the labrum (27). Chondral damage at the femoral head and acetabular cartilage was assessed with a semiquantitative grading scale (28). The presence of pincer morphology was assessed using the crossover sign on anteroposterior pelvic radiographs (29). In addition, the level of hip OA was evaluated on anteroposterior pelvic radiographs using the Tönnis grading system (18).

Sample size

Sample size was determined based on mean ± standard deviation changes in HOS ADL from baseline to 7-month follow up in patients responsive (22 ±18 points) vs. non-responsive (4 ± 7 points) to pain and function improvements following hip arthroscopy for FAIS (30). Considering an effect size of 1.2, 5% type I error, 10% type II error, and 5% of patients lost to follow-up, a *t* test calculation indicated a sample size of 17 each group (34 in total).

Data analysis

Descriptive data are presented as mean ± standard deviation (continuous data) or as number and percentage (dichotomous data). Intention-to-treat analysis was performed including all patients who completed the assessments at week 6. For missing data, the "last observation carried forward" technique was used. Per-protocol analysis was performed including only those patients who completed the assessments at week 18. After controlling for assumptions, two-way ANCOVAs with repeated measures were used to evaluate changes in hip pain and function, quality of life and hip muscle strength (continuous data) at different times and differences between responders vs. non-responders, while adjusting for baseline values. Fisher’s Least Significant Difference tests were used for post-hoc pairwise comparisons of the means. Fisher's Exact tests were used to evaluate changes in the proportion of patients with good dynamic pelvic control (dichotomous data) at different times and differences between responders vs. non-responders. Baseline characteristics were compared between responders vs. non-responders using unpaired *t* tests (continuous data) and relative risks with Fisher's Exact tests (dichotomous data). Changes, differences and relative risks were reported as means with 95% confidence intervals. Minimal clinically important differences (MCID) of 8 points for HOS ADL (31), 14 points for HOS Sport (31), 15 points for EQ-VAS (20), and 10% for hip muscle strength were used for the interpretation of results. Statistical analyses were performed using PASW Statistics Version 18.0 (IBM Corporation, Armonk, NY). Significance level was set at $P<0.05$.

RESULTS

Therapy feasibility

Sixty patients were eligible for the study between October 2014 and September 2016 (Figure 1). Thirty-four (57%) consecutive patients were enrolled in the study. Five patients (15%) were lost during the study: 3 before week 6 because of insufficient therapy adherence, and 2 between week 6 and 12 because of injuries unrelated to the study. Eight patients (25%) had hip surgery: 3 between week 6 and 12, 2 between week 12 and 18, and 3 between week 18 and 1 year follow-up. Thirty-one patients had assessments at week 6 and were included in the intention-to-treat analysis. Twenty-four patients had assessments at week 18 and were included in the per-protocol analysis. All patients (100%) included in the analyses attended more than 80% of the therapy sessions. No adverse event was recorded.

Therapy responsiveness

A total of 3 (10%), 11 (35%) and 9 (29%) patients reported their hip pain to be much better, 12 (39%), 10 (32%) and 7 (22%) better, 7 (22%), 5 (16%) and 6 (19%) somewhat better, 7 (22%), 3 (10%) and 5 (16%) unchanged, and 2 (7%), 2 (7%) and 4 (14%) worse at week 6, 12 and 18, respectively, compared with baseline. A total of 15 (48%), 21 (68%) and 16 (52%) patients had good outcome, that is, hip pain much better or better compared with baseline, at week 6, 12 and 18, respectively. Demographics, anthropometrics, physical examination outcomes and symptoms duration did not differ between responders vs. non-responders at baseline (Table 1). The prevalence of patients who were taking pain killer for hip symptoms at baseline was significantly higher in non-responders than responders (27% vs. 0%, P=0.043).

Hip pain, function and quality of life

HOS ADL and HOS Sport significantly improved and reached the respective MCID at week 12 and 18 compared with baseline in responders, but not in non-responders (Table 2). Significantly larger increases in HOS ADL and HOS Sport were observed in responders vs. non-responders at week 18 compared with baseline, achieving the respective MCID. EQ-VAS significantly improved and approached the MCID at week 12 and 18 compared with baseline in responders, but not in non-responders. Significantly larger increase in EQ-VAS was observed in responders vs. non-responders at week 18 compared with baseline, approaching the MCID.

Hip muscle strength

Strength of all hip muscle groups significantly improved and reached the MCID at week 12 and 18 compared with baseline in responders (Table 3). Strength of hip internal rotators, external rotators and flexors, but not of the other hip muscle groups, significantly increased and achieved the MCID at week 12 and 18 compared with baseline in non-responders. Significantly larger increase in hip abductor strength was observed in responders vs. non-responders at week 12 and 18 compared with baseline, reaching the MCID.

Dynamic pelvic control

The prevalence of patients performing the single-limb squat with good dynamic pelvis 2 control significantly increased at week 18 compared with baseline in responders (19% to 63%. *P*=0.029), but not in non-responders (Table 4).

Hip imaging

The prevalence of patients with cam severity grade 3 was significantly higher in non-responders than in responders (40% vs. 6%, *P*=0.037, Table 5). The mean ± SD alpha angle was 73 ± 6° in patients with cam severity grade 3, 68 ± 5° with grade 2, 60 ± 3° with grade 1 and 54 ± 2° with grade 0. The prevalence of pincer morphology and intra-articular damage did not differ significantly between responders vs. non-responders. All patients had Tönnis grade 0.

Per-protocol analysis

Results of per-protocol analysis were comparable with those of intention-to-treat analysis (Supplementary Tables S2-S6). In contrast with intention-to-treat analysis, HOS ADL and HOS Sport significantly improved and reached the respective MCID in non-responders at week 12 compared with baseline, and change in HOS Sport did not differ in responders vs. non-responders at week 18 compared with baseline. Moreover, change in hip abductor strength did not differ in responders vs. non-responders at week 18 compared with baseline.

DISCUSSION

In this preliminary study, half of the patients with FAIS did benefit at short-term follow-up from 12 weeks of semi-standardized and progressive exercise therapy. Responders improved their hip function during ADL and sport activities, hip abductor strength and pelvic control in the frontal plane during single-limb squat, whereas non-responders did not. In addition, the large majority of patients with severe cam morphology were not responsive to exercise therapy.

Strengths and limitations

To our knowledge, this is the first study that evaluates differences in hip function, strength and morphology between responders vs. non-responders to exercise therapy for FAIS. The identification of patient characteristics, which may predict the success vs. failure of exercise therapy, is of interest in orthopaedics and sport medicine to provide valid non-surgical treatment options and strengthen surgical indications (7). The main limitation of this study is the absence of a control group. At the time of study planning, we could not find an ethically and methodologically valid control treatment to compare the outcomes of exercise therapy. Thus, we decided to treat all patients with exercise therapy, and retrospectively analyse differences between responders and non-responders. In addition, a patient-reported outcome, that is, the GTO for hip pain, was used to categorize patients as responders vs. non-responders. An objective measure, such as hip cartilage health assessed using MRI arthrography, could be used to avoid subjective bias (32), since treatments for FAIS should aim at reducing pain, but also at decelerating the hip degenerative process (4). However, hip joint degeneration changes were not expected in this study because of the short-term follow-up. Future studies with longer follow-ups should evaluate if exercise therapy might decelerate the degenerative process of the hip joint in patients with FAIS, preventing the development of hip OA. Moreover, differences in hip function, strength and morphology changes following exercise therapy were not evaluated between female and male patients. Since we found no sex-difference in exercise therapy responsiveness (Table 1), sex was not used as covariate in our analyses. In addition, the small sample size did not allow us to use sex as a main factor in our analyses. Future larger studies should however consider sex-differences for exercise therapy effectiveness due to different clinical (33) and functional characteristics (13,34) presented by female and male patients with FAIS.

Therapy responsiveness

The responsiveness to exercise therapy found in our study (52%) was similar or better compared with that observed in earlier studies (35,36), and similar to the outcomes reported for hip surgery for FAIS at short-term follow-up (20). Hunt et al observed that only 33% of their patients with FAIS could benefit from a trial of exercise therapy (35), while Wright et al and Impellizzeri et al had 60% of their patients reporting good outcomes after 6 weeks of exercise therapy, and at 6 months after hip surgery, respectively (20,36). The relatively poor outcomes reported by Hunt et al may be the result of the low and variable amount of therapy provided to the patients (i.e., mean of 6 sessions, range: 1 to 19) (35). In the present study, 8 patients (25%) decided to have hip surgery, as controlled until 1 year follow-up. All of them had a poor outcome at the last available follow-up, with 4 patients reporting their hip pain to be worse, 3 unchanged, and 1 somewhat better compared with baseline. These patients generally reported lower hip function and strength outcomes compared with other non-responders, as confirmed by the per-protocol analysis, in which only the best non-responders were included. Indeed, larger improvements in hip function and strength were observed for non-responders in the per-protocol than intention-to-treat analysis, resulting in less differences compared with responders. The observed surgery rate was lower than in earlier studies (53% to 65%) (35,36). The level of symptoms and hip joint degeneration may explain the higher surgery rates in previous studies, with patients being on average older than our patients (34 vs. 24 years) (35,36), having more hip pain and worse hip function (36), and most of them being already considered for surgery at baseline (35,36).

Dynamic hip joint stability

The responsiveness to improvements in hip abductor strength and dynamic pelvic control while performing a single-limb squat was associated with good therapy outcomes. These results strengthen the rationale that an improved dynamic stability of the femoroacetabular joint may reduce the mechanical load on the acetabular labrum, resulting in a reduction of symptoms (10). In particular, hip abductor muscles seem to be determinant for achieving a good dynamic pelvic control (15,37), and femoroacetabular joint stability (38). Nevertheless, future research needs to confirm these observations by investigating the effects of hip muscle strength and pain changes following exercise therapy on hip joint kinematics, loadings and contact stresses using motion analysis, musculoskeletal and finite element modelling, respectively. In addition, exercise therapy shorter than 12 weeks, as well as therapy discontinuation after 12 weeks of training, might be associated with poor therapy outcomes. Indeed, the prevalence of patients with good outcome increased from 48% after 6 weeks to 68% after 12 weeks of therapy. Moreover, patients with good outcome did not achieve a clinically relevant improvement in hip pain and function before 12 weeks of therapy. We speculate that 6 weeks of therapy are not enough to induce the neuromuscular adaptations responsible for dynamic hip stability improvements and symptoms reduction (39). In addition, the prevalence of patients with a good outcome decreased from 68% after 12 weeks of therapy to 52% at follow-up 6 weeks later. We assume that the worsening of symptoms in some patients may be the result of insufficient training stimuli after completion of supervised therapy, not enabling to preserve the achieved benefits.

Cam morphology

The presence of severe cam morphology seems to predict the failure of exercise therapy. In our study, a total of 7 patients (23%) presented with severe cam morphology: 6 were not responsive while only 1 was responsive to exercise therapy. We assume that large morphological abnormalities at the proximal femur do not allow to improve the hip neuromuscular function and dynamic hip stability following exercise therapy, so as to reduce the symptoms. In our study, severe cam deformities corresponded to an alpha angle of 73 ± 6°. There is increasing evidence that patients with an alpha angle >78° present a high risk to develop hip OA (40). Taken together, these findings suggest that patients with severe cam morphology are probably not the best candidates for non-surgical treatment options, but rather for hip surgery.

Conclusions

Half of patients with FAIS benefits at short term follow-up from exercise therapy by experiencing a clinically relevant hip pain reduction. Responsiveness to improvements in hip function, hip abductor strength and dynamic pelvic control is associated with a good therapy outcome. In contrast, the presence of severe cam morphology is associated with a poor therapy outcome. Future randomised controlled trials comparing exercise therapy with a control treatment (e.g., passive physical therapy) should be conducted to confirm these preliminary results.

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FIGURE LEGENDS

Figure 1. Study flowchart

Table 1. Patients' characteristics at baseline

	Mean ± SD / Number (%)			Mean difference (95% CI)/ Relative risk (95% CI)
	All	Responders	Non-responders	
Demographics				
Gender (women)	20 (65)	11 (69)	9 (60)	1.21 (0.57 - 2.58)
Age (years)	25 ± 5	24 ± 5	25 ± 5	1 (-3 - 4)
Anthropometrics				
Body mass (kg)	68 ± 12	65 ± 13	70 ± 11	5 (-4 - 14)
Height (cm)	172 ± 9	170 ± 9	173 ± 8	3 (-4 - 9)
BMI (kg/m^2)	23 ± 4	22 ± 4	23 ± 3	1 (-1 - 4)
Provocation tests (positive)				
FADIR test	29 (94)	16 (100)	13 (87)	2.23 (1.49 - 3.34)
FABER test	19 (61)	12 (75)	7 (47)	1.81 (0.89 - 3.69)
Posterior impingement test	17 (55)	10 (63)	7 (47)	1.39 (0.67 - 2.87)
Range of motion (°)				
Hip flexion	103 ± 12	101 ± 11	104 ± 14	3 (-6 - 12)
Hip internal rotation	25 ± 10	25 ± 11	24 ± 10	-1 (-8 - 7)
Hip abduction	35 ± 5	35 ± 5	35 ± 5	0 (-4 - 3)
Symptoms duration (months)	40 ± 36	37 ± 32	41 ± 36	4 (-20 - 29)
Contralateral hip pain	13 (42)	5 (31)	8 (53)	0.63 (0.31 - 1.30)
Pain killer intake	4 (13)	0 (0)	4 (27)	0.41* (0.26 - 0.64)

BMI, body mass index; FADIR, flexion-adduction-internal rotation; FABER, flexion-abduction-external rotation; CI, confidence interval. Mean ± SD and differences are reported for continuous data; numbers, percentages and relative risks are reported for dichotomous data. * indicates significant difference at $P<0.05$. Responders, n=16; non-responders, n=15.

Table 2. Hip pain, function and quality of life

	Scores by week Mean ± SD				Score changes within group Mean (95% CI)			Score differences between groups Mean (95% CI)		
	0	6	12	18	Week 6	Week 12	Week 18	Week 6	Week 12	Week 18
HOS ADL (0 to 100)										
Responders	85 ± 9	91 ± 6	95 ± 7	95 ± 6	6*** (3 - 10)	10*** (7 - 14)	10*** (7 - 14)	4 (-1 - 11)	5 (-1 - 11)	10** (5 - 17)
Non-responders	80 ± 18	82 ± 19	85 ± 17	80 ± 22	2 (-2 - 5)	5** (1 - 9)	0 (-4 - 3)			
HOS Sport (0 to 100)										
Responders	71 ± 17	82 ± 15	90 ± 12	91 ± 10	11*** (6 - 16)	19*** (14 - 24)	20*** (15 - 25)	8 (0 - 16)	10* (2 - 18)	14** (6 - 22)
Non-responders	68 ± 24	71 ± 22	77 ± 22	74 ± 23	3 (-2 - 8)	9*** (4 - 14)	6* (1 - 11)			
EQ-VAS (0 to 100)										
Responders	78 ± 11	87 ± 10	91 ± 7	91 ± 9	9*** (4 - 13)	13*** (8 - 17)	13*** (8 - 17)	4 (-4 - 10)	8* (1 - 14)	13** (5 - 19)
Non-responders	75 ± 16	80 ± 14	80 ± 13	75 ± 12	5* (1 - 10)	5* (1 - 10)	0 (-4 - 5)			

HOS, Hip Outcome Score; ADL, activities of daily living; EQ-VAS, EuroQol-Visual Analogue Scale; CI, confidence interval. *, ** and *** indicate significant difference at $P<0.05$, $P<0.01$ and $P<0.001$, respectively. Responders, n=16; non-responders, n=15.

Table 3. Hip muscle strength

Hip muscle group	Muscle strength (Nm/kg)						
	Scores by week Mean ± SD			Score changes within group Mean (95% CI) / %		Score differences between groups Mean (95% CI) / %	
	0	12	18	Week 12	Week 18	Week 12	Week 18
Adductors							
Responders	2.29 ± 0.61	2.73 ± 0.84	2.62 ± 0.79	0.44^{***} (0.27 - 0.61)/19	0.33^{***} (0.16 - 0.50)/14	0.38^{**} (0.11 - 0.64)/17	0.22 (-0.04 - 0.48)/11
Non-responders	2.48 ± 0.69	2.54 ± 0.62	2.59 ± 0.76	0.06 (-0.11 - 0.24)/2	0.11 (-0.06 - 0.29)/4		
Abductors							
Responders	1.80 ± 0.41	2.07 ± 0.40	2.07 ± 0.36	0.27^{***} (0.18 - 0.36)/15	0.27^{***} (0.18 - 0.36)/15	0.20^{**} (0.07 - 0.32)/11	0.17^{*} (0.04 - 0.30)/10
Non-responders	1.86 ± 0.45	1.93 ± 0.43	1.96 ± 0.49	0.07 (0.02 - 0.16)/4	0.10^{*} (0.01 - 0.19)/5		
Internal rotators							
Responders	0.74 ± 0.25	0.96 ± 0.20	0.88 ± 0.18	0.22^{***} (0.14 - 0.29)/30	0.14^{**} (0.06 - 0.21)/19	0.09 (-0.02 - 0.19)/13	0.00 (-0.11 - 0.11)/1
Non-responders	0.76 ± 0.34	0.89 ± 0.29	0.90 ± 0.29	0.13^{**} (0.06 - 0.21)/17	0.14^{**} (0.06 - 0.21)/18		
External rotators							
Responders	0.53 ± 0.20	0.68 ± 0.15	0.63 ± 0.15	0.15^{***} (0.10 - 0.21)/28	0.10^{***} (0.05 - 0.16)/19	0.04 (-0.04 - 0.13)/8	-0.02 (-0.11 - 0.07)/-2
Non-responders	0.56 ± 0.24	0.67 ± 0.22	0.68 ± 0.25	0.11^{***} (0.05 - 0.16)/20	0.12^{***} (0.06 - 0.17)/21		
Flexors							
Responders	1.31 ± 0.45	1.51 ± 0.46	1.50 ± 0.39	0.20^{***} (0.12 - 0.28)/15	0.19^{***} (0.11 - 0.27)/14	0.03 (-0.10 - 0.17)/2	0.03 (-0.10 - 0.17)/2
Non-responders	1.36 ± 0.31	1.53 ± 0.37	1.52 ± 0.41	0.17^{***} (0.08 - 0.25)/13	0.16^{***} (0.07 - 0.24)/12		

Extensors							
Responders	2.24 ± 0.61	2.70 ± 0.77	2.47 ± 0.64	0.46*** (0.25 - 0.66)/20	0.23* (0.02 - 0.44)/10	0.32 (-0.03 - 0.67)/14	0.04 (-0.31 - 0.39)/2
Non-responders	2.40 ± 0.83	2.54 ± 0.72	2.59 ± 0.76	0.14 (-0.08 - 0.35)/6	0.19 (-0.02 - 0.41)/8		

CI, confidence interval. *, ** and *** indicate significant difference at P<0.05, P<0.01 and P<0.001, respectively. Responders, n=16; non-responders, n=15.

Table 4. Dynamic pelvic control

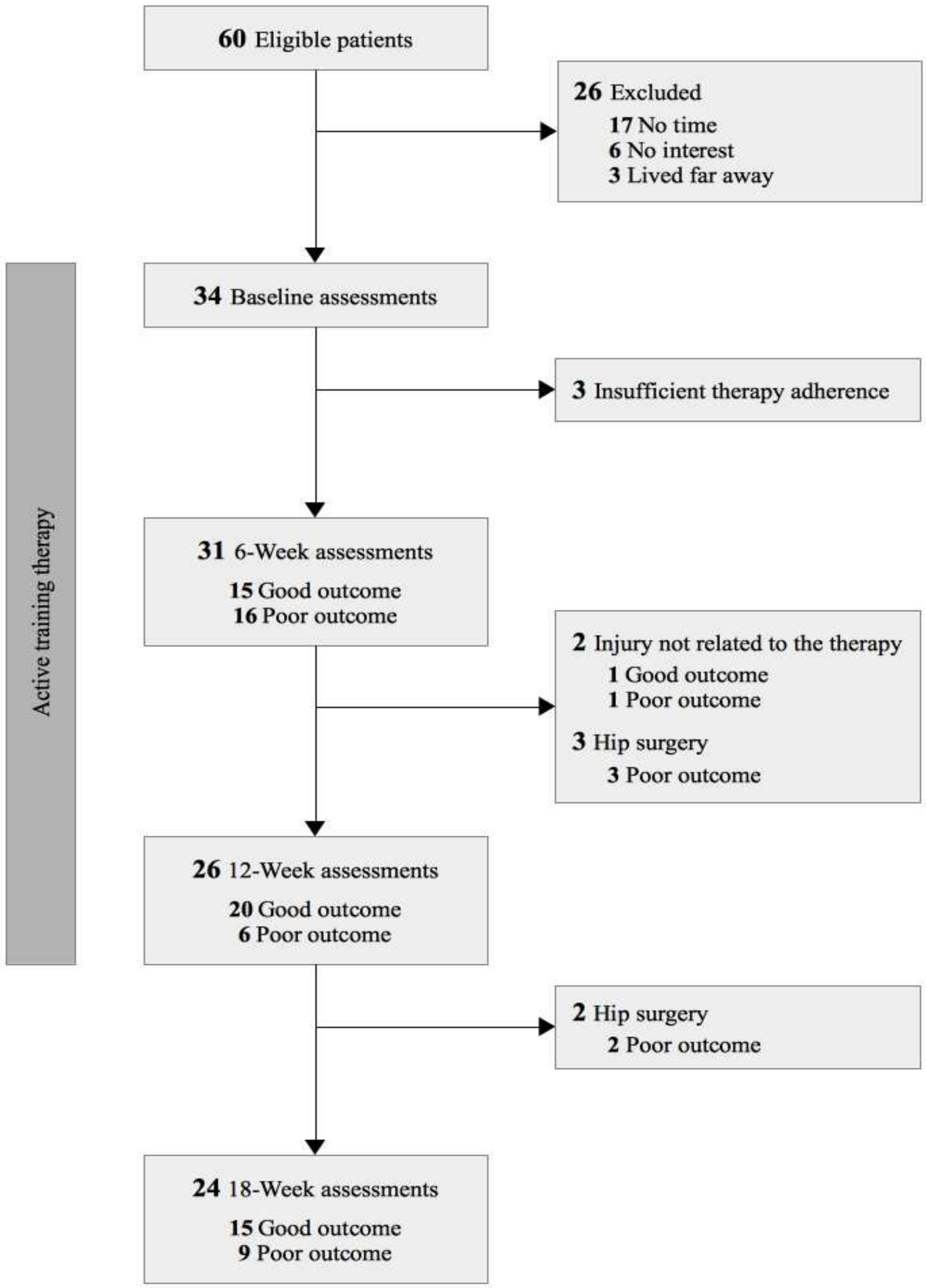
	Good performers Number (%)			Good performer changes within group Number (%)		Good performer differences between groups Number (%)	
	0	12	18	Week 12	Week 18	Week 12	Week 18
Single-limb squat							
Pelvis 1							
Responders	4 (25)	8 (50)	8 (50)	4 (25)	4 (25)	3 (18)	2 (12)
Non-responders	3 (20)	4 (27)	5 (33)	1 (7)	2 (13)		
Pelvis 2							
Responders	3 (19)	9 (56)	10 (63)	6 (37)	7* (44)	5 (31)	5 (31)
Non-responders	4 (27)	5 (33)	6 (40)	1 (6)	2 (13)		
Single-limb hop lunge							
Pelvis 1							
Responders	2 (13)	4 (25)	5 (31)	2 (12)	3 (18)	0 (0)	1 (5)
Non-responders	3 (20)	5 (33)	5 (33)	2 (13)	2 (13)		
Pelvis 2							
Responders	2 (13)	4 (25)	5 (31)	2 (12)	3 (18)	0 (0)	1 (5)
Non-responders	3 (20)	5 (33)	5 (33)	2 (13)	2 (13) 13)		

Pelvis 1, pelvis moves out of neutral in the frontal or transversal plane; Pelvis 2, pelvis moves away from midline; CI, confidence interval. * indicates significant difference at *P*<0.05. Responders, n=16; non-responders, n=15.

Table 5. Hip morphology and intra-articular damage patterns

	Number (%)		Relative risk (95% CI)
	Responders	Non-responders	
Cam severity grade			
Grade 3	1 (6)	6 (40)	0.44* (0.24 - 0.80)
Grade 2	11 (69)	7 (47)	1.58 (0.77 - 3.25)
Grade 1	2 (12)	1 (7)	1.50 (0.29 - 7.75)
Grade 0	2 (12)	1 (7)	1.50 (0.29 - 7.75)
Crossover sign	13 (81)	14 (93)	0.48 (0.08 - 2.74)
Acetabular labral tear	13 (81)	13 (87)	0.80 (0.26 - 2.50)
Cartilage damage			
Acetabulum	3 (19)	6 (40)	0.61 (0.31 - 1.21)
Femur	3 (19)	2 (13)	1.25 (0.40 - 3.91)

CI, confidence interval. * indicates significant difference at *P*<0.05. Responders, n=16; non-responders, n=15.


60 Eligible patients
26 Excluded
17 No time
6 No interest
3 Lived far away
34 Baseline assessments
3 Insufficient therapy adherence
Active training therapy
31 6-Week assessments
15 Good outcome
16 Poor outcome
2 Injury not related to the therapy
1 Good outcome
1 Poor outcome
3 Hip surgery
3 Poor outcome
26 12-Week assessments
20 Good outcome
6 Poor outcome
2 Hip surgery
2 Poor outcome
24 18-Week assessments
15 Good outcome
9 Poor outcome